MIL-STD-889B
NOTICE 1
21 November 1979

MILITARY STANDARD

DISSIMILAR METALS

TO ALL HOLDERS OF MIL-STD-889B:

1. THE FOLLOWING PAGES OF MIL-STD-889B HAVE BEEN REVISED AND SUPERSEDE THE PAGES LISTED:

NEW PAGE	DATE	SUPERSEDED PAGE	DATE
1	7 July 1976	(REPRINT WITHOUT CHANGE)	7 July 1976
2	21 November 1979	2	7 July 1976
3	21 November 1979	3	7 July 1976
4	7 July 1976	(REPRINT WITHOUT CHANGE)	7 July 1976
5	21 November 1979	5	7 July 1976
6	21 November 1979	6	7 July 1976

2. RETAIN THIS NOTICE AND INSERT BEFORE TABLE OF CONTENTS.

3. Holders of MIL-STD-889B will verify that page changes and additions indicated above have been entered. This notice page will be retained as a check sheet. This issuance, together with appended pages, is a separate publication. Each notice is to be retained by stocking points until the Military Standard is completely revised or canceled.

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MILITARY STANDARD

DISSIMILAR METALS

1. SCOPE.

1.1 Purpose. This standard defines and classifies dissimilar metals, and establishes requirements for protecting coupled dissimilar metals, with attention directed to the anodic member of the couple, against corrosion.

1.1.1 Applicability. This standard is applicable to all military equipment parts, components and assemblies.

2. REFERENCED DOCUMENTS.

2.1 Issues of documents. The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of this standard to the extent specified herein.

SPECIFICATIONS

MILITARY

MIL-S-8802	Sealing Compound, Temperature-Resistant, Integral Fuel Tanks and Fuel Cell Cavities, High Adhesion

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. DEFINITIONS.

3.1 Dissimilar metals. This standard terms metals dissimilar when two metal specimens are in contact or otherwise electrically connected to each other in a conductive solution and generate an electric current.

3.2 Galvanic corrosion. Galvanic corrosion manifests itself in the accelerated corrosion caused to the more active metal (anode) of a dissimilar metal couple in an electrolyte solution or medium, and decreased corrosive effects on the less active metal (cathode), as compared to the corrosion of the individual metals, when not connected, in the same electrolyte environment.

3.3 Galvanic series. A galvanic series is a listing of metals and alloys based on their order and tendency to corrode independently, in a particular electrolyte solution or other environment. This tendency for dissolution or corrosion is related to the electrical potential of the metal in conductive medium. Galvanic corrosion is inherently affected by the relative position of the galvanic series of the metals constituting the couple. Metals closely positioned in the series will have electrical potentials nearer one another, whereas with greater divergence in position, greater differences in potential will prevail. Galvanic effects, i.e., corrosion of the anode will in the former condition be minimal, the latter condition will exhibit more significant corrosive effects. A galvanic series for corrosion structural metals, for sea water, is shown in Table II. Table I shall be used as a guide in determining the relative compatibility of dissimilar metal combinations. Compatibility does not indicate a complete freedom from galvanic action.

4. GENERAL STATEMENTS. (Not Applicable)

5. DETAILED REQUIREMENTS.

5.1 Minimizing dissimilar metal corrosion.

5.1.1 When dissimilar metals are used in intimate contact, suitable protection against galvanic corrosion shall be applied. In some environments particularly with metals such as magnesium, steel, zinc, aluminum, in contact with copper, stainless steel, nickel, galvanic corrosion may be appreciable. Consequently, care should be taken to protect the anodic member by proper electrical insulation of the joint or by excluding the electrolyte if this is feasible.

5.1.2 Table II list metals in the order of their relative activity in sea water environment. The list begins with the more active (anodic) metal and procedes down to the least active (cathodic) metal of the galvanic series. A "galvanic series" applies to a particular electrolyte solution; hence for each specific solution which is expected to be encountered for actual use, a different order or series will ensue. Galvanic series relationships are useful as a guide for selecting metals to be joined, will help the selection of metals having minimal tendency to interact galvanically, or will indicate the need or degree of protection to be applied to lessen the expected potential interactions. Generally, the closer one metal is to another in the series, the more compatible they will be, i.e., the galvanic effects will be minimal; conversely, the farther one metal is from another, the greater will be the effect. In a galvanic couple, the metal higher in the series represents the anode, and will corrode preferentially in the environment.

5.1.3 Metals widely separated in the galvanic series must be protected if they are to be joined. Appropriate measures should be taken to avoid contact. This can be accomplished by applying to the cathodic member a sacrificial metal coating having a potential similar to or near that of the anodic member; by sealing to insure that the faying surfaces are water-tight; by painting or coating all surfaces to increase the resistance of electrical circuit.

5.1.4 A small anodic area relative to the cathodic area should be avoided. The same metal or more noble (cathodic) metals should be utilized for small fasteners, and bolts. The larger is the relative anode area, the lower the galvanic current density on the anode, the lesser the attack. The galvanic corrosion effect may be considered as inverse to the anode-cathode area ratio.

5.1.5 Metals exposed to sea water environments shall be corrosion and stress-corrosion resistant or shall be processed to resist corrosion and stress-corrosion. Irrespective of the metals involved, all exposed edges should be sealed with a suitable sealant material conforming to MIL-S-8802. When non-compatible materials are joined, an interposing material compatible with each shall be used.

5.1.6 Materials other than true metals, i.e., non-metallic materials, which must be joined to metals, should be considered as metallic materials, unless there is supporting evidence to the contrary. If these materials are essentially free of corrosive agents (salts), free of

TABLE I.

GUIDE–TO USE OF JOINED STRUCTURAL METALS AND ALLOYS AND PROTECTIVE SYSTEMS– FOR SERVICE IN SEA WATER, MARINE ATMOSPHERE AND INDUSTRIAL ATMOSPHERE

JOINED TO 2ND METAL OR METAL ALLOY (columns): ACTIVE (ANODIC) → NOBLE (LESS ACTIVE–CATHODIC)

1ST METAL OR METAL ALLOY (rows): ACTIVE (ANODIC) → NOBLE (LESS ACTIVE–CATHODIC)

Each cell: metal 1, sea water, metal 2 / marine atmosphere, industrial atmosphere.

	1ST METAL OR METAL ALLOY	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	
A	MAGNESIUM	1 G	1 I 2 / C C	1 I 3 / C C	1 I 4 / I I	1 I 4 / I I	1 I 5 / I I	1 I 6 / I I	1 I 6 / I I	1 I 7 / I I	1 I 8 / I I	1 I 9 / I I	1 I 9 / I I	1 I 9 / I I	1 I 9 / I I	1 I 9 / I I	1 I 9 / I I	1 I 10 / I I	1 I 11 / I I	1 I 12 / I I	1 I 13 / I I	A
B	ZINC, ZINC COATING		2 G	2 C 3 / C C	2 I 4 / C C	2 I 4 / C C	2 I 5 / I I	2 I 6 / I I	2 I 6 / I I	2 I 7 / I I	2 I 8 / I I	2 I 9 / I I	2 I 9 / I I	2 I 9 / I I	2 I 9 / I I	2 I 9 / I I	2 I 9 / I I	2 I 10 / I I	2 I 11 / I I	2 I 12 / I I	2 I 13 / I I	B
C	CADMIUM BERYLLIUM			3 G	3 I 4 / C C	3 I 4 / C C	3 I 5 / I I	3 I 5 / I I	3 I 6 / I I	3 I 7 / I I	3 I 8 / I I	3 I 9 / I I	3 I 9 / I I	3 I 9 / I I	3 I 9 / I I	3 I 9 / I I	3 I 9 / I I	3 I 10 / I I	3 I 11 / I I	3 I 12 / I I	3 I 13 / I I	C
D	ALUMINUM ALUMINUM–Mg ALUMINUM–Zn				4 G	4 C 4 / C C	4 I 5 / I I	4 I 5 / I I	4 I 6 / I I	4 I 7 / I I	4 I 8 / I I	4 I 9 / I I	4 I 9 / I I	4 I 9 / I I	4 I 9 / I I	4 I 9 / I I	4 I 9 / I I	4 I 10 / I I	4 I 11 / I I	4 I 12 / I I	4 I 13 / I I	D
E	ALUMINUM–Cu					4 G	4 I 5 / I I	4 I 6 / I I	4 I 6 / I I	4 I 7 / I I	4 I 8 / I I	4 I 9 / I I	4 I 9 / I I	4 I 9 / I I	4 I 9 / I I	4 I 9 / I I	4 I 9 / I I	4 I 10 / I I	4 I 11 / I I	4 I 12 / I I	4 I 13 / I I	E
F	STEELS – CARBON LOW ALLOY						5 G	5 I 6 / I C	5 I 5 / I I	5 I 7 / I I	5 I 8 / I I	5 I 9 / I I	5 I 9 / I I	5 I 9 / I I	5 I 9 / I I	5 I 9 / I I	5 I 9 / C C	5 I 10 / I I	5 I 11 / I I	5 I 12 / I I	5 I 13 / I I	F
G	LEAD							6 G	6 C 6 / C C	6 I 7 / C C	6 I 8 / C C	6 I 9 / C C	6 I 9 / C C	6 I 9 / I I	6 I 9 / I C	6 I 9 / I C	6 I 9 / I C	6 I 10 / I C	6 I 11 / C C	6 I 12 / I C	6 I 13 / I C	G
H	TIN TIN–Pb INDIUM								6 G	6 I 7 / I I	6 I 8 / I C	5 I 9 / I C	6 I 9 / C C	6 I 9 / C C	6 I 9 / C C	6 I 9 / C C	6 C 9 / C C	6 I 10 / C C	6 C 11 / C C	6 I 12 / C C	6 I 13 / I I	H
I	ST. STEELS – MARTENSITIC FERRITIC									7 G	7 I 8 / I C	7 I 9 / I I	7 I 9 / I I	7 I 9 / I C	7 I 9 / I I	7 I 9 / I I	7 I 9 / I I	7 I 10 / I I	7 I 11 / I I	7 I 12 / I I	7 I 13 / I I	I
J	CHROMIUM MOLYBDENUM TUNGSTEN										8 G	8 C 9 / C C	8 I 9 / C C	8 I 9 / I C	8 I 9 / I I	8 I 9 / C C	8 I 9 / C C	8 I 10 / C C	8 I 11 / C C	8 I 12 / C C	8 I 13 / C C	J
K	ST. STEELS–AUST. PH. SUPER STRENGTH, HEAT RESISTANT											9 G	9 I 9 / I I	9 I 9 / I I	9 I 9 / I I	9 I 9 / C C	9 I 9 / C C	9 I 10 / C C	9 I 11 / C C	9 I 12 / C C	9 I 13 / C C	K
L	BRASS–Pb BRONZE												9 G	9 I 9 / C C	9 I 9 / C C	9 I 9 / I C	9 I 9 / C C	9 I 10 / I C	9 I 11 / C C	9 I 12 / C C	9 I 13 / C C	L
M	BRASS–LOW Cu BRONZE–LOW Cu													9 G	9 I 9 / C C	9 I 9 / C C	9 I 9 / C C	9 I 10 / I C	9 I 11 / C C	9 I 12 / I C	9 I 13 / I C	M
N	BRASS–HIGH Cu BRONZE–HIGH Cu														9 G	9 I 9 / I C	9 I 9 / C C	9 I 10 / I C	9 I 11 / C C	9 I 12 / I C	9 I 13 / I C	N
O	COPPER–HIGH Ni MONEL															9 G	9 I 9 / C C	9 I 10 / C C	9 I 11 / C C	9 I 12 / C C	9 I 13 / C C	O
P	NICKEL COBALT																9 G	9 I 10 / C C	9 I 11 / C C	9 I 12 / C C	9 I 13 / C C	P
Q	TITANIUM																	10 G	10 I 11 / C C	10 I 12 / C C	10 I 13 / C C	Q
R	SILVER																		11 G	11 C 12 / C C	11 I 13 / C C	R
S	PALLADIUM RHODIUM GOLD PLATINUM																			12 G	12 C 13 / C C	S
T	GRAPHITE																				13 G	T

INFORMATION ON THIS CHART IS PRESENTED FOR EQUAL EXPOSED AREAS OF EACH METAL COMPRISING THE COUPLE.

KEY: METAL 1 (upper left) — METAL 2 (upper right) — SEA WATER (center) — MARINE ATMOSPHERE (lower left) — INDUSTRIAL ATMOSPHERE (lower right)

NUMERICAL NOTATIONS REFER TO SURFACE TREATING AND FINISHING SYSTEMS, LISTED IN APPENDIX A FOR EACH METAL GROUP, FOR AMELIORATING CORROSION OF JOINED METALS. THE SYSTEMS ARE ARRANGED IN APPENDIX A IN DECREASING ORDER OF EFFECTIVENESS. AN OPTIMUM SYSTEM IS PRESENTED IN EACH CASE, FOR USE WITH JOINED SIMILAR OR DIFFERENT METALS INTENDED FOR SERVICE IN SEVERE ENVIRONMENT. ALTERNATIVE SYSTEMS ARE GIVEN FOR USE IN SERVICE SITUATIONS THAT PRECLUDE THE MAXIMUM PROTECTIVE SYSTEM, OR FOR MILDER ENVIRONMENT SERVICE APPLICATIONS.

LETTER NOTATIONS, C OR I, SIGNIFY COMPATIBILITY OR INCOMPATIBILITY OF JOINED METALS IN THE SPECIFIC ENVIRONMENT. OCCASIONALLY, C OR I, IS NOT CLEARLY RESOLVABLE AND IN SUCH BORDERLINE CASES I IS INDICATED. FURTHER, C INDICATES NEGLIGIBLE GALVANIC INTERACTION BETWEEN BARE, DISSIMILAR METALS WHEN JOINED AND SUBJECTED TO THE SPECIFIC ENVIRONMENT; AND I SIGNIFIES SIGNIFICANT GALVANIC CORROSION OF BARE, DISSIMILAR METALS WHEN JOINED AND SUBJECTED TO THE SPECIFIC ENVIRONMENT.

G: SIGNIFIES COMPATIBILITY OF SAME–METAL COUPLE, BARE, IN SEA WATER, MARINE ATMOSPHERE, OR INDUSTRIAL ATMOSPHERE.

TABLE II. Galvanic series of selected metals in seawater.

PER: Army Missile Command Report RS-TR-67-11, Practical Galvanic Series.

Active (Anodic)

Magnesium (Mg)
Mg Alloy AZ-31B
MG Alloy HK-31A
Zinc (hot-dip, die cast or plated)
Beryllium (hot pressed)
Aluminum (Al) 7072 cl. on 7075
Al alloy 2014-T3
Al alloy 1160-H14
Al alloy 7079-T6
Cadmium (plated)
Uranium
Al alloy 218 (die cast)
Al alloy 5052-0
Al alloy 5052-H12
Al alloy 5456-0, H353
Al alloy 5052-H32
Al alloy 1100-0
Al alloy 3003-H25
Al alloy 6061-T6
Al alloy A360 (die cast)
Al alloy 7075-T6
Al alloy 1160-H14
Al alloy 6061-0
Indium
Al alloy 2014-0
Al alloy 2024-T4
Al alloy 5052-H16
Tin (plated)
Stainless steel 430 (active)
Lead
Steel 1010
Iron, cast
Stainless steel 410 (active)
Copper (plated, cast or wrought)
Nickel (plated)
Chromium (plated)
Tantalum
AM350 (active)
Stainless steel 310 (active)
Stainless steel 301 (active)
Stainless steel 304 (active)
Stainless steel 430 (passive)
Stainless steel 410 (passive)
Stainless steel 17-7 PH (active)
Tungsten
Niobium (Columbium) 1% Zr
Brass, yellow, 268
Uranium 8% Mo.
Brass, Naval, 464
Yellow brass
Muntz metal 280
Brass (plated)
Nickel-silver (18% Ni)
Stainless steel 316L (active)
Bronze 220
Copper 110
Red brass
Stainless steel 347 (active)
Molybdenum, Comm pure
Copper-Nickel 715
Admiralty brass
Stainless steel 202 (active)
Bronze, Phosphor 534 (B-1)
Monel 400
Stainless steel 201 (active)
Carpenter 20 (active)
Stainless steel 321 (active)
Stainless steel 316 (active)
Stainless steel 309 (passive)
Stainless steel 17-7 PH (passive)
Silicone Bronze 655

Stainless steel 304 (passive)
Stainless steel 301 (passive)
Stainless steel 321 (passive)
Stainless steel 201 (passive)
Stainless steel 286 (active)
Stainless steel 316L (passive)
AM355 (active)
Stainless steel 202 (passive)
Carpenter 20 (passive)
AM355 (passive)
A286 (passive)
Titanium 5Al, 2.5 Sn.
Titanium 13V, 11Cr, 3Al. (annealed)
Titanium 6Al, 4V (solution treated and aged)
Titanium 6Al, 4V (annealed)
Titanium 8 Mn
Titanium 13V, 11Cr 3Al (solution treated and aged)
Titanum 75A
AM350 (passive)
Silver
Gold
Graphite

Noble (Less Active-Cathodic)